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## NOTES ON SOME PROBLEMS OF ADAPTATION: 9. CTENIDIAL VARIATION IN CHITON.<sup>1</sup>

L. H. SNYDER AND W. J. CROZIER,

(1901-)

(1892-)

ZOOLOGICAL LABORATORY, RUTGERS COLLEGE.

1. The respiratory organs of the Amphineura comprise a more or less extensive row of branchial filaments on either side of the body, in the groove between girdle and foot. Within the species it is known that the number of these ctenidia is variable. It is likewise known that the right and left ctenidial sets of an individual may differ in number of included gills. Published observations on these points have been summarized by Pelseneer (1920, p. 201). It appears that in some species the number of ctenidia may increase with the size of the animal; in others it seems to decrease; while in still others no correlation is very evident between size of animal and number of gills. We have sought to determine the nature and extent of ctenidial variation in *Chiton tuberculatus* of the Bermudas, having in mind the possibility of evidence upon the following points:

- (1) Ctenidial variation as correlated with size (age),
- (2) with sex, and
- (3) with habitat; and
- (4) indications of asymmetry.

The gill plumes were counted in 100 individuals, of a range of sizes. The length of the fourth shell-valve, along its mid-line, was measured as an index of size. By means of graphs such as that given by Arey and Crozier (1919, p. 164) the length of the fourth valve may be translated into terms of the length of the individual; the curled condition of many of the specimens, as preserved, precluded direct determination of their lengths. It is sufficient to note that the length of the shell-valve varies directly with the total size of the animal, though the relation is not exactly a linear one,

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owing to the effects of erosion and its consequences (Arey and Crozier, 1919).

The total number of ctenidia is at first 64-66, and increases in a fairly regular manner as growth proceeds. The average maximum number is about 98. The data are given in Table I.

TABLE I.

|                          | Length of valve 4 in mm. |   |   |   |   |    |    |   |    |    |    |    |    |    |     |
|--------------------------|--------------------------|---|---|---|---|----|----|---|----|----|----|----|----|----|-----|
|                          | 0                        | 1 | 2 | 3 | 4 | 5  | 6  | 7 | 8  | 9  | 10 | 11 | 12 | 13 |     |
| Total number of branchia | 64-66                    | 2 |   |   |   |    |    |   |    |    |    |    |    |    | 2   |
|                          | 67-69                    |   |   |   |   |    |    |   |    |    |    |    |    |    |     |
|                          | 70-72                    |   |   |   |   |    |    |   |    |    |    |    |    |    |     |
|                          | 73-75                    | 1 | 1 |   |   |    |    |   |    |    |    |    |    |    | 2   |
|                          | 76-78                    |   | 1 | 1 |   |    |    |   |    |    |    |    |    |    | 2   |
|                          | 79-81                    |   | 1 | 1 | 1 |    |    |   |    |    |    |    |    |    | 2   |
|                          | 82-84                    |   |   | 2 | 1 | 2  | 1  |   |    |    |    |    |    |    | 6   |
|                          | 85-87                    |   | 2 |   |   |    | 1  |   |    |    |    |    | 1  |    | 4   |
|                          | 88-90                    |   |   |   | 2 | 4  |    | 1 | 1  | 1  |    |    |    |    | 9   |
|                          | 91-93                    |   |   | 1 | 2 | 4  | 6  | 2 | 1  |    |    | 1  |    | 1  | 19  |
|                          | 94-96                    |   |   | 3 |   | 1  | 4  | 1 | 1  | 2  | 3  |    | 1  |    | 16  |
|                          | 97-99                    |   |   |   |   |    | 1  | 2 | 10 | 2  |    | 1  |    | 1  | 17  |
|                          | 100-102                  |   |   |   |   | 2  | 1  | 4 | 4  |    |    | 1  | 1  |    | 13  |
|                          | 103-105                  |   |   |   |   |    |    | 1 | 3  |    |    |    |    |    | 4   |
|                          | 106-108                  |   |   |   |   |    | 1  | 1 |    |    |    | 1  |    |    | 3   |
|                          |                          | 3 | 5 | 8 | 6 | 11 | 15 | 8 | 19 | 12 | 3  | 2  | 4  | 3  | 100 |

DISTRIBUTION OF TOTAL NUMBERS OF CTENIDIA IN RELATION TO LENGTH OF FOURTH SHELL-VALVE; ALL INDIVIDUALS.

2. Since the number of gills is determined in part through growth, it is of interest to learn if the extent of the gill series is influenced by sex. Fig. 1 makes it plain that such influence, if real, must be slight. It is possible that there is on the average a slightly higher number of ctenidia in the males, when the comparison is made of males and females equal in size; on the basis of *age* this slight difference is increased, for the females are the larger, at the same age (unpublished data). It is doubtful if this

difference can be correlated with relative activity. New gills are in all probability added at the posterior end of the ctenidial series. Occasionally gill plumes are observed with divided tips (such as have been figured by Pelseneer, 1920, p. 204).

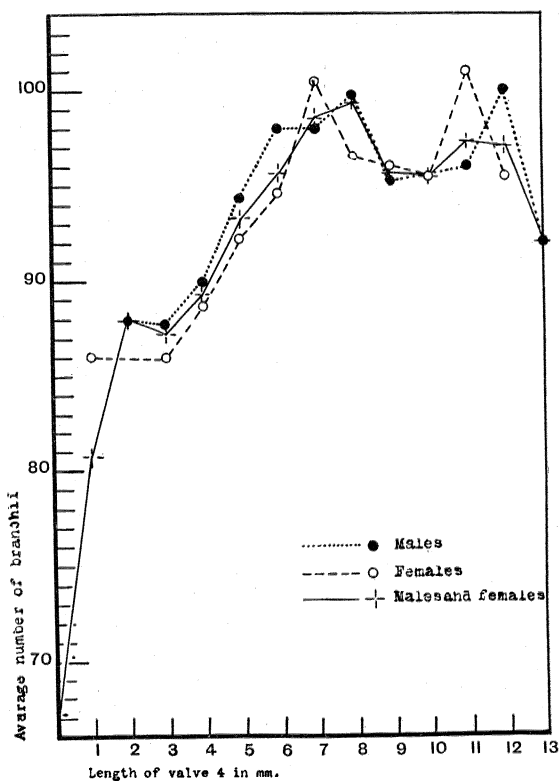


FIG. 1.

It appears from Fig. 1 that the full number of ctenidia is established before maximum growth is attained. It is unlikely that there is a real *decrease* in the number of ctenidia with extreme age (cf. Table I.). The number of gills is frequently mentioned as a subsidiary character in descriptions of species, hence recognition of the variation we record may be of taxonomic importance.

3. This inquiry began with the thought that the total number of gills might be influenced by habitat. The number of individuals at our disposal is small, but sufficient for preliminary study of the point.

Our *Chiton tuberculatus* were secured from two well-contrasted situations (cf. Crozier, 1918): an exposed ocean beach on the south shore of Bermuda (here referred to as "South Shore"), and the shores of an enclosed sound, Great Sound. In Fig. 2 the mean ctenidial frequency for each size class is contrasted for these two locations. Clearly there is no great difference between the

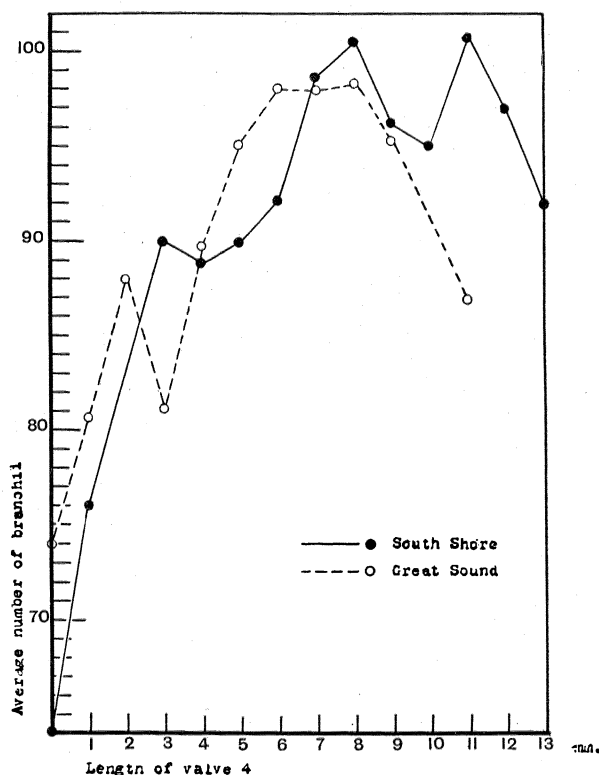


FIG. 2.

two sets of observations, though the lower number of ctenidia in the younger animals from the South Shore may perhaps prove significant.

4. Is it possible that the asymmetry of gasteropods is in some manner foreshadowed among the chitons? The two liver-lobes of young chitons are at first symmetrical, but later the right lobe becomes the smaller and is pushed anteriorly (Pelseneer, 1906,

p. 44); it has been noted that the number of the auriculo-ventricular connections of the heart may be dissimilar on the two sides (Pelseneer, 1897, p. 23); several instances of valve-fusion seemed asymmetrical (Crozier, 1919); and the existence of minor asymmetries in the two gill series has been recorded several times (Pelseneer, 1897; 1920, p. 201). But the published data fail to cover the possibility of definite correlation with superior growth on the right or on the left side.

Our counts show that the distribution of asymmetries of the ctenidia follows a purely random course; the absolute amount of asymmetry, moreover, is small. When excess of gill-plumes on the right side as compared with the left is reckoned as *plus*, on the left side as compared with the right as *minus*, a frequency curve is

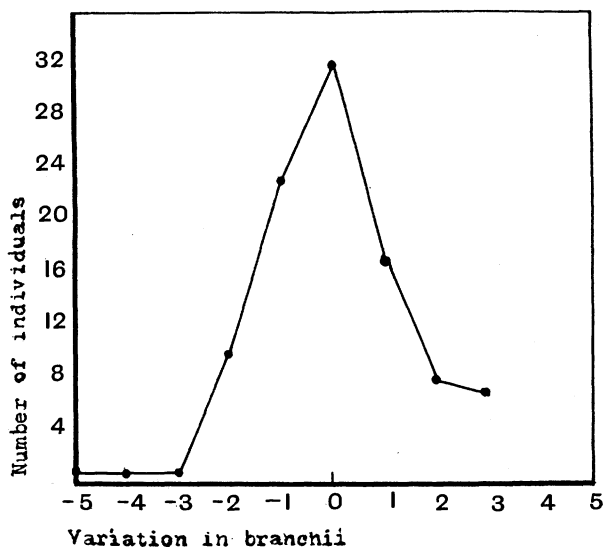


FIG. 3.

obtained (Fig. 3) indicating an essentially chance distribution. It follows that the asymmetry is merely an accident of growth, giving a measure of the independence of the two sides in forming new gills. On this view, the extent of ctenidial asymmetry should increase, as a rule, with size. Table II. shows that this is the case.

TABLE II.

RELATION OF ASYMMETRY (EXCESS NUMBER OF GILLS ON ONE SIDE) TO SIZE  
(CLASSES ACCORDING TO LENGTH OF VALVE 4.)

| Class Centers. |         |         |         |          |
|----------------|---------|---------|---------|----------|
|                | 0.2 mm. | 0.5 mm. | 0.8 mm. | 0.11 mm. |
| 0.....         | 12      | 5       | 7       | 5        |
| 1.....         | 4       | 19      | 12      | 4        |
| 2.....         | 2       | 8       | 7       | 1        |
| 3.....         | 1       |         | 5       | 1        |
| 4.....         |         |         | 1       |          |
| 5.....         |         | 1       |         |          |

There is no apparent correlation of asymmetry with sex or with habitat. In the majority of cases the number of gill-plumes differs on the two sides, but the difference is usually not more than one. The asymmetry can therefore hardly be connected with the torsion of the body in gasteropods.<sup>2</sup>

*Summary.*—In *Chiton tuberculatus* at Bermuda the number of ctenidia increases from 32 on either side, in individuals about 1.0 cm. long, to an average of 49 on a side in individuals of the largest size (9–10 cm. long). The increase in the number of gills is at first quite rapid, so that the maximal number is achieved before the animal is 6.0 cm. long. The mean number of ctenidia is a little less in females than in males of the same size or age.

On an exposed ocean beach these chitons have the same number of gills as found in the population of an inclosed sound.

Minor asymmetries in number (1 to 5) are the rule when the two gill series of an individual are compared. Asymmetry follows a random distribution; it is an accident of growth and has no morphological significance.

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<sup>2</sup> Two instances were found of a curious malformation, which may be noted here. At the level of the fourth valve a tough "bridge" of tissue had grown across from the lateral wall of the foot to the girdle, forming an arch over the ctenidial channel. These "bridges" were about 3 mm. wide.

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